Path difference under monotonic and cyclic loading in anisotropic media

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Abstract

Additive manufacturing has garnered significant attention due to its flexibility in modeling and its capacity to easily design complex microstructures (1). Given that microstructure plays a crucial role in determining crack propagation paths (2), additive manufacturing has become increasingly relevant in the study of fracture mechanics. In this work, we used samples fabricated by Fused Deposition Modeling, which exhibit a strongly anisotropic behavior in fracture toughness while retaining isotropy in elasticity. This anisotropic behavior arises from employing the 'criss-cross' printing strategy as reported in (3). This strategy involved filling each layer with a selected infill angle or raster angle (angle of deposited material with respect to the notch), with successive layers arranged orthogonally.
By applying monotonic and cyclic loading, we observed notable differences in crack propagation paths between quasistatic and fatigue cracks. Under monotonic loading, cracks propagate along the direction of the raster angle (referred to as the 'weak plane'), consistent with predictions from the Generalized Maximum Energy Release Rate (GMERR) criterion. In contrast, fatigue cracks subjected to cyclic loading exhibit a distinctly different paths, following a straight path by KII = 0 in agreement with the Principle of Local Symmetry (PLS). A similar behavior has been observed in fatigue phase-field computational models with two-fold anisotropy (4), indicating that this path difference is a general phenomenon. Both experiments and numerical computations suggest that quasistatic crack paths are primarily dictated by the microstructure, while fatigue crack paths are influenced by the symmetry of the loading (5).

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